

The present invention is particularly directed to the use of flexible software and machine control technology to rapidly select appropriate tools, spin and tilt the crankshafts 32, and shift the tools to each of the various positions needed for machining holes in a crankshaft 32. It is much quicker and 5 easier to change the software driven electronic controls of the machining apparatus 20 than to physically change dedicated transfer line equipment.

What is claimed is:

1. An apparatus for machining holes in crankshafts at 10 various angular positions about a longitudinal axis through the crankshaft and at various tilt angles to the rotational axis, comprising:

a frame;

a rotational means on the frame for supporting a crank- 15 shaft and for rotating the crankshaft about the crankshaft's longitudinal axis to present different angular positions for the machining of holes;

a machine head mounted on the frame with a tool, 20 movable along a plunging axis to present the tool to the crankshaft to machine holes therein; and

tilt means on the frame mounting the crankshaft to tilt the crankshaft at various angles to the plunging axis so that 25 holes may be machined at various rotational positions about the crankshaft and at various tilt angles to its longitudinal axis.

2. An apparatus in accordance with claim 1 wherein rotational means comprises a crankshaft supporting fixture, 30 means in the fixture mounting the crankshaft for turning about the rotational axis of the crankshaft within the fixture; and wherein the tilt means includes pivot means on the frame for pivotally mounting the fixture to pivot relative to the plunging axis.

3. The apparatus of claim 2 wherein a slide means of the 35 machine frame guides the machine head for travel along the plunging axis, another slide means of the machine frame guides the machine head for travel along a first positioning axis normal to the plunging axis, and another slide means of the machine frame guides the machine head for travel along 40 a second positioning axis that is normal to both the first positioning axis and the plunging axis.

4. The apparatus of claim 1 further comprising means for 45 storing a plurality of tools and tool support bushings, adjacent the machine head for automatic transfer of different tools to the machine head.

5. The apparatus of claim 1 further comprising means for 50 positioning a tool support bushing in correct position between the crankshaft and the tool.

6. The apparatus of claim 1 wherein a second rotational 55 means is provided on the fixture for supporting a second crankshaft for synchronous rotational positioning of the second crankshaft with the first crankshaft; and

a second machine head is provided having a tool, syn- 60 chronously movable with the first machine head along the plunging axis to present tools to the pair of crankshafts after the crankshafts have been rotatably positioned and tilted relative to the plunging axis.

7. The apparatus of claim 1, wherein pivot means on the 65 frame are provided and the tilt means comprise a fixture mounted on the pivot means for tilting about an axis through the pivot means.

8. An apparatus for machining holes in crankshafts at 70 various angular positions about a longitudinal axis through the crankshaft and at various tilt angles to the rotational axis, comprising:

a frame;

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- a fixture on the frame having means for supporting a crankshaft for rotational positioning of the crankshaft about the crankshaft's longitudinal axis;
- means on the fixture for turning the crankshaft in a first, angular direction about the crankshaft's longitudinal axis while the crankshaft is supported in the fixture to present different peripheral surface sections of the crankshaft;
- a first machine head for carrying a tool, movable along three axes;
- the first axis being a vertical axis for positioning the tool vertically relative to the crankshaft;
- the second axis being a horizontal axis for positioning the tool horizontally relative to the crankshaft;
- the third axis being a horizontal plunging axis which is normal to the first and second axes, for presenting the tool to the crankshaft; and
- tilt means on the frame for tilting the fixture and the crankshaft carried thereon through a second angular rotation about a tilt axis and relative to the plunging axis to machine holes at various angles to the longitudinal axis and at various peripheral locations about the crankshaft.
9. The apparatus of claim 8 further comprising:
- a second machine head having a tool, synchronously movable with the first machine head along three axes; and
- wherein, the fixture has means for supporting a pair of crankshafts for the synchronous rotational positioning of the crankshafts about the crankshafts' longitudinal axes.
10. An apparatus for machining holes in crankshafts at various angular positions about a longitudinal axis through the crankshaft and at various tilt angles to the rotational axis, comprising:
- a frame;
- a fixture having means for supporting a plurality of crankshafts for the synchronous rotational positioning of the crankshafts about the crankshafts' longitudinal axes;
- tilt means on the frame including trunnions mounting the fixture for tilting in an angular direction about a horizontal axis through a central portion of the fixture to present the crankshafts at various tilt angles to the plunging axis;
- means on the fixture for turning each of the crankshafts about their respective, longitudinal axes in a second angular direction while the crankshafts are supported in the fixture;
- a plurality of machine heads having tools, synchronously movable along three axes: the first axis being a vertical axis for positioning the tools vertically relative to the crankshafts; the second axis being a horizontal axis, parallel to the axis of the trunnions, for positioning the tools horizontally relative to the crankshafts; the third axis being a plunging axis, normal to the first and second axes, for presenting the tools to the crankshafts after the crankshafts have been rotatably positioned about both the axis of the trunnions and the crankshafts' longitudinal axes;
- means for storing a plurality of tools and tool support bushings, adjacent the machine heads for automatic transfer of different tools and tool support bushings to the machine heads; and
- means for positioning the tool support bushings in correct position between the plurality of crankshafts and tools.

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11. An apparatus for machining holes in crankshafts at various angular positions about a longitudinal axis through the crankshaft and at various tilt angles to the rotational axis, comprising:

a frame: 5

a crankshaft workholder mounted on the frame for supporting a crankshaft for rotation about the crankshaft's longitudinal axis to present different angular positions for the machining of holes:

a machine head mounted on the frame with a tool, 10
movable along a plunging axis to present the tool to the crankshaft to machine holes therein;

tilt means on the frame mounting the crankshaft workholder to tilt the crankshaft workholder at various 15
angles to the plunging axis so that holes may be machined at various rotational positions about the crankshaft and at various tilt angles to its longitudinal axis; and

an open face on one side of the crankshaft workholder to 20
allow loading and unloading of a crankshaft when the workholder is tilted to a crankshaft loading position.

12. An apparatus in accordance with claim 11 wherein a headstock and a tailstock for rotating the crankshaft are 25
mounted on the crankshaft workholder; and

means for moving the headstock relative to the tailstock to load or unload a crankshaft are on one side of the crankshaft workholder, leaving an opposite side open for lifting from an dropping into of crankshafts.

13. An apparatus in accordance with claim 11 wherein an 30
automatic tool changer is movable from a remote position to a tool changing position between the crankshaft workholder and the machine head.

14. An apparatus in accordance with claim 13 wherein 35
means on the frame guide the automatic tool changer to slide laterally into a space created when the workholder is tilted to create more space between it and the machine head.

15. A method of machining crankshafts comprising the steps of:

loading a crankshaft into a pivotable fixture; 40

tilting the fixture about a first tilt axis relative to a tool-plunging axis;

rotating the crankshaft in the fixture about the longitudinal axis of the crankshaft to align the hole location with the 45
plunging axis;

machining a first hole in the crankshaft;

moving a tool head carrying a tool in three orthogonal directions relative to the crankshaft in the fixture to

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position the tool for machining another hole along the length of the crankshaft:

machining a second hole in the crankshaft; and

unloading the crankshaft with machined holes therein.

5 16. A method of machining crankshafts in accordance with claim 15 including the step of loading a pair of crankshafts in the fixture and machining each of the crankshafts simultaneously.

10 17. A method of machining crankshafts in accordance with claim 15 including the step of providing a machine tool having at least three axes with the plunging axis being a horizontal axis, and in which the step of moving the tool relative to the crankshaft includes the step of shifting the tool head vertically along a vertical axis.

15 18. A method of machining crankshafts comprising the steps of:

positioning a crankshaft fixture to have an open face facing upwardly to receive at least one crankshaft therein;

20 loading at least one crankshaft into the fixture through the open face thereon;

tilting the fixture to present the crankshaft to a tool and at a predetermined angle to the longitudinal axis of the crankshaft;

25 rotating the crankshaft in the fixture to present a predetermined location on the crankshaft to be machined;

30 plunging the tool into the workpiece to machine a hole at the predetermined location and at the predetermined angle, to the longitudinal axis of the crankshaft;

removing the tool from the hole formed in the workpiece; and

35 tilting the fixture to position the crankshaft for removal from the fixture.

19. A method in accordance with claim 18 including the further step of providing an automatic toolchanger at a position remote from the machine head;

40 shifting the automatic toolchanger laterally into a space between the machine head and the fixture; and

automatically changing tools on the machine head.

20. A method in accordance with claim 19 including the step of rotating the fixture to shift a portion thereof from its crankshaft presenting position for machining to enlarge the space to accommodate the automatic tool changers lateral movement to the tool changing position between the fixture and the machine head.

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5 21. An apparatus for machining holes in a crankshaft at various circumferential positions about a rotational axis of the crankshaft and at various angles to the rotational axis, the apparatus comprising:

a frame;

10 a first support on the frame for supporting a crankshaft for rotating about the crankshaft rotational axis to present different circumferential positions for machining of holes;

a first drive associated with the first support for rotating the crankshaft about its rotational axis so that holes may be machined at various circumferential positions about the crankshaft;

15 a machine head mounted on the frame with a tool movable along a plunging axis to present the tool to the crankshaft to machine holes therein;

20 a second support on the frame for supporting the crankshaft for shifting relative to the plunging axis so that holes may be machined at various angles relative to the rotational axis; and

a second drive associated with the second support to shift the crankshaft relative to the plunging axis.

25 22. An apparatus in accordance with Claim 21 comprising:

a mount on the frame for mounting the second support for rotating about a horizontal axis.

30 23. An apparatus in accordance with Claim 21 comprising:

a bushing support for supporting a tool while machining the crankshaft; and

a positioning apparatus for positioning the bushing in a predetermined position relative to the tool and the crankshaft.

5 24. An apparatus in accordance with Claim 23 comprising:

a bushing changer for an automatic changing of the bushing being used for machining the crankshaft.

10 25. An apparatus in accordance with Claim 21 wherein the second support has a crankshaft loading and unloading position; and

15 the second support and crankshaft are rotated from the loading and unloading position to machine holes at various angles to the plunging axis.

20 26. An apparatus in accordance with Claim 25 comprising:

a mount on the frame mounting the second support for rotating the crankshaft about a horizontal axis to machine holes at various angles to the plunging axis.

25 27. An apparatus in accordance with Claim 21 comprising:

a tool and bushing magazine in which tools and bushings are stored and removed for being changed automatically.

30 28. An apparatus in accordance with Claim 21 comprising:

vertical guides on the frame for guiding the machine head to move vertically relative to the frame.

29. An apparatus in accordance with Claim 21 comprising:

5 a lateral drive for shifting the tool and its plunging axis horizontally to different positions for machining holes at various positions axially along the crankshaft.

10 30. An apparatus in accordance with Claim 29 wherein the frame includes horizontal guides for guiding the machine head to slide on the frame in a horizontal direction as the lateral drive shifts the machine head to different positions for machining holes at various positions axially along the crankshaft.

15 31. An apparatus in accordance with Claim 21 comprising:

20 a second machine head having a tool for machining a second crankshaft simultaneously while the first crankshaft is machined; and

a work support for supporting two or more crankshafts adjacent to each other for machining two or more crankshafts simultaneously with respective holes at the same angle to the axes of the crankshafts.

25 32. An apparatus for machining holes in crankshafts at various circumferential positions about a longitudinal axis through the crankshaft and at various angles to the longitudinal axis, the apparatus comprising:

a frame;

30 a first support and first drive carried by the frame for supporting a crankshaft and for rotating the crankshaft about the crankshaft's longitudinal axis to present different circumferential positions thereof for the machining of holes;

a machine head mounted on the frame with a tool, movable along a plunging axis to present the tool to the crankshaft to machine holes therein; and

a second support and second drive on the frame mounting the crankshaft for turning the crankshaft to be at various angles relative to the plunging axis so that holes may be machined at various circumferential positions about the crankshaft and at various angles to its longitudinal axis.

33. An apparatus for machining holes in crankshafts at various rotational positions about a longitudinal axis through the crankshaft and at various angles to the longitudinal axis, the apparatus comprising:

a frame;

a support for supporting a crankshaft for rotational positioning of the crankshaft about the crankshaft's longitudinal axis;

a rotational drive carried by the support for turning the crankshaft about the crankshaft's longitudinal axis while the crankshaft is supported in the support to present different peripheral surface sections of the crankshaft for machining;

a first machine head for carrying a tool along a first vertical axis for positioning the tool vertically relative to the crankshaft;

a positioning mechanism that allows relative positioning between the machine head tool and crankshaft to be adjusted along a second horizontal axis;

the tool being positioned by the machine head along a horizontal plunging axis which is normal to the first and second axes, for presenting the tool to the crankshaft; and

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a pivotable mount for the support and for pivoting the crankshaft carried thereon about a pivot axis and relative to the plunging axis to allow holes to be machined at various angles to the longitudinal axis and at various peripheral locations about the crankshaft.

34. The apparatus of Claim 33 further comprising:
a second machine head having a tool,
synchronously movable with the first machine head; and
wherein, the support comprises a fixture
carrying a pair of crankshafts for the synchronous
rotational positioning of the crankshafts about the
crankshafts' longitudinal axes.

35. An apparatus for machining holes in a
crankshaft at various angles relative to a longitudinal
axis of the crankshaft, the apparatus comprising:
a machine head for carrying a tool that
machines holes in the crankshaft;
a machine support that advances the tool along
a plunging axis toward the crankshaft;
a crankshaft loading and unloading fixture
having an open accessible side that can be shifted to
allow for crankshaft loading and unloading operation; and
a drive for the fixture that shifts the open
side between a first position with the open side
generally facing upward to allow for overhead loading and
unloading operations to take place in an unimpeded manner
and a second position with the open side generally facing
the machine head.

36. The apparatus of claim 35 wherein the fixture
includes a pivot axis that extends normal to the plunging

axis, and the drive pivots the fixture about the pivot axis between the first and second positions.

5 37. The apparatus of claim 36 wherein the second position of the crankshaft fixture orients the crankshaft axis to be at various angles relative to the plunging axis for machining holes in the crankshaft at predetermined angles to the crankshaft axis.

10 38. The apparatus of claim 35 including a crankshaft support and associated drive that allow the crankshaft to be rotated about its longitudinal axis for machining holes at different circumferential positions about the crankshaft.

15 39. The apparatus of claim 35 wherein the crankshaft fixture has a pivot axis to allow the crankshaft to be inclined at predetermined angles relative to the plunging axis.

20 40. The apparatus of claim 35 wherein the crankshaft fixture includes a pair of crankshaft supports for allowing a pair of crankshafts to be simultaneously loaded into the fixture or unloaded therefrom.